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TOMATO LATE BLIGHT CONTROL IN 1950

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The late blight disease of potato and tomato, caused by *Phytophthora infestans* (Mont.) de Bary, has been present on tomatoes in Ohio in varying amounts for many years (6), but it was not until 1946 that it caused serious losses in this and many other states (1, 3, 4, 5). The disease has been present in Ohio every year since that date but did not again become severe, except in restricted areas, until 1950 (9). It was reported as present each year on tomatoes in home gardens and some commercial plantings. It caused severe losses in many fields at scattered locations over the state in 1946, and was particularly destructive in the tomato canning area in northwestern Ohio. The disease was again present in isolated fields and many home gardens in 1947 and 1948 (6, 7). In 1949, it again became widespread throughout the canning area, but appeared too late in the season to do much damage except in a few fields.

In 1950, it appeared along the Ohio River in June and further north in July. By August 15, it was present in several fields in northern Ohio (9, 10), and developed rapidly under the influence of a series of cool nights accompanied by considerable rainfall. By mid-September, the disease had reached epidemic proportions in many localities and losses through defoliation of the vines and rotting of the fruit were heavy in many unsprayed or poorly protected fields.

During the last 10 or more years, field experiments located at various places in Ohio have been designed to study the efficiency of fungicidal formulations and application schedules for the control of tomato diseases, including late blight. However, comparatively little data on late blight control were obtained until 1946 because of the virtual absence of the disease until that date. Even in that year late blight appeared in but one of six experimental fields, where it destroyed only 4 percent of the fruits in the untreated check plots. In 1947, it was present in varying degrees of severity in 8 of 10 experimental fields, but in 1948, it appeared in only two of six experimental areas (6, 7). In 1949, the disease appeared in only one of the five fields that were being sprayed experimentally, and caused little loss even there (8). This dearth of infection by late blight was ended in 1950 when the disease appeared in every one of six experimental blocks located at, or near, Wooster. It became very destructive in the untreated plots in three of these experiments, and the severity with which it attacked afforded an excellent opportunity to observe the effectiveness of various fungicidal formulations in the control of the disease. Some of the results obtained in 1950 are presented in this paper.

Weather Factors

Plant diseases are regulated in their initiation and development by the environmental conditions to which they are subjected. Temperature and moisture are two of the most important regulatory factors so far as most diseases are concerned, and this is especially true for tomato late blight. The disease develops most rapidly between 55° and 65° F. and is checked by temperatures of 75° F. and above. Moisture in the form of dew or rain, and a temperature of 50 to 60° F. for 12 to 18 hours, is most favorable for spore germination and infection. The disease will continue to develop rapidly so long as temperatures do not go over 70° F., and the infection of additional foliage and fruit will occur whenever the temperature and moisture conditions described above exist for 12 hours or more.

May, with a mean temperature of 59.6° F., was 1.0° F. above the average daily mean for that month. A total rainfall of 5.05 inches was 1.18 inches above the average. This total included two heavy rains, one of 1.36 inches on the 15th and one of 1.38 inches on the 25th.

A mean temperature in June of 66.3° F. was 1.6° F. below the daily average. There were eight nights when the minimum fell below 50°. A rainfall of 5.28 inches was 1.17 inches above the average. There were two heavy rains, one of 1.66 inches on the 3rd and one of 1.83 inches on the 26th.

July, with a mean temperature of 69.7° F., was 2.2° F. below the daily average for that month. This included two nights below 50° F., and 20 below 60° F. A rainfall of 4.31 inches was 0.37 inches above the monthly average. There were two rather heavy showers, one of 0.80 inches on the 3rd and a considerable one of 1.87 inches on the 31st.

August also continued cool and an average daily mean of 69.7° F. was 1.9° F. below the average. Late blight appeared on tomatoes about the middle of the month. That this might have been expected from the standpoint of temperatures is indicated by the fact that there were 9 nights when the minimum fell below 50° F., and there were a total of 18 nights below 60° F. There were at least three rains heavy enough to encourage the spread and development of late blight, 0.90 inches on the 9th, 1.00 inch on the 18th, and 1.21 inches on the 28th. A total of 3.67 inches for the month was 0.10 inch above the average.

September continued favorable for late blight (which became severe) with a daily mean of 62.1° F., which was 1.9° F. below the average. There were 14 nights with temperatures below 50° F., and a total of 24 below 60° F. The minimum on September 24 was 35° F. It was 36° F. on the 26th and 37° F. on the 27th. The first killing frost occurred on October 5. A rainfall of only 1.58 inches was 1.50 inches below the normal for that month. There were only two storms of any consequence. These were 0.47 inches on the 1st and 0.33 inches on the 21st.

It requires only a casual inspection of these weather data to show there were probably several periods from early June to late August when the temperature was sufficiently low, and the humidity sufficiently high, for late blight spores to germinate and cause infection. There were several favorable intervals in late July and early August and, as might have been anticipated, the disease did appear by the middle of August. It then developed rapidly and became severe on tomatoes over most of northwestern Ohio by mid-September. It also appeared in many potato fields throughout Ohio during September and early October.

Methods

All of the fungicidal formulations used in the four experiments discussed here were applied with a tractor-mounted, independently-powered sprayer at the rate of 160 gallons per acre and at a pressure of 300 pounds per square inch. Each plot contained 10 plants spaced at 30-inch intervals in rows planted 6 feet apart. Four replicates, arranged in a pattern of random distribution, were used for each treatment. The original plan called for seven sprays at 10-day intervals, but this was varied somewhat as the season progressed. The first application in each experiment was made a few days before or after July 15, and the last about September 10. There was, of course, some variation in the different schedules, since only one experiment could be sprayed on any one day. The 10-day interval between applications was varied in a few instances about mid-August, when late blight began to spread rapidly, in an effort to slow down the progress of the disease. This 10-day schedule favored the copper-containing formulations and handicapped the organic fungicides to some extent, since many of the latter are best able to control late blight when they are applied every 5 to 7 days. However, most tomato growers, and particularly those who sell their crop to a cannery, can hardly afford to apply more than five or six treatments during the season. The plants usually need protection against anthracnose by July 20, and until late September if late blight and other foliage and fruit diseases are to be warded off. Thus, even if the first treatment were delayed until July 25, the last one, in a 5-application schedule with a 10-day interval, would be applied on September 3. An application of a copper fungicide made that early in September would hardly give adequate protection against disease until October 1, and few, if any, of the organic materials will give effective disease control for more than 10 days after they are applied.

Beginning early in August, the plots were inspected every few days for the presence of such foliage diseases as early blight, Septoria leaf spot, late blight, and for spray injury. When the check plots were judged to have lost about 25 percent of their leaves, from whatever cause, all plots in the experiment were examined and scored according to the percentage of defoliation. This procedure was then repeated at weekly intervals until defoliation on the untreated checks was approximately 100 percent, or until the end of the picking season, whichever came first.

The ripe fruit was picked, weighed and counted at weekly intervals. Each fruit was examined at the time of harvest for the presence of lesions caused by anthracnose, early blight, late blight, or various soil rots. The fruits were sorted into two classes only. The culls included those that were unfit for use, and the remainder consisted of those which were considered usable. The weight of each group was determined and recorded. The tomato variety used in all of these experiments was the second generation of the cross of Stokesdale × Rutgers.

Secondary counts were made of the number of fruits having either anthracnose or late blight. During the past season, it was found to be desirable to pick any and all fruits that were obviously infected with late blight at each picking. Otherwise, many of those with the disease became so soft by the next picking date, one week later, that they could not be removed from the plant and weighed.

Materials Key

The various fungicides used in the disease-control experiments discussed in this paper are listed below, together with their chemical composition:

1. Tribasic—Cupric trioxysulfate (tribasic copper sulfate). Contains 50% copper as the metallic equivalent.
2. Cop-O-Zink—Basic salts of copper and zinc. Contains 40% copper and 11% zinc as the metallic equivalents.
3. COC-S—Basic copper chloride (2 parts) plus basic copper sulfate (1 part). Contains 56% copper as the metallic equivalent.
4. Robertson fungicide—A metallic copper core plus a cuprous oxide sheath around each particle equivalent to about 20% of the total weight. Contains approximately 93% copper as the metallic equivalent.
5. Phelps Dodge copper paste—Plate-like particles of metallic copper. Formulated to contain 50% copper as the metallic equivalent.

6. Copper cupferron—Cupric N-Nitroso-N-phenylhydroxylamine. Formulated to contain 13% copper as the metallic equivalent.
7. Bordeaux mixture—Copper sulfate plus hydrated lime plus water to form a complex series of copper hydroxides.
8. Dithane D-14 (nabam)—Aqueous solution of disodium ethylene bis dithiocarbamate. Formulated to contain 19-20% of the active ingredient.
9. Parzate, dry (zineb)—Zinc ethylene bis dithiocarbamate. Formulated to contain 65% of the active ingredient.
10. MnEBD—Manganese ethylene bis dithiocarbamate. Formulated to contain 76-80% of the active ingredient.
11. Zerlate (ziram)—Zinc dimethyl dithiocarbamate. Formulated to contain 76% of the active ingredent.
12. Methasan (ziram)—Zinc dimethyl dithiocarbamate. Formulated as a slurry to contain 50% of the active ingredent, or as a wettable powder at about 99% active.
13. Zac—A zinc dimethyl dithiocarbamate cyclohexylamine complex. Formulated as a slurry to contain 40% of the active ingredient, or as a wettable powder at 25% active.
14. Orthocide 406—N-trichloromethylthio tetrahydrophthalimide. Formulated to contain 50% of the active ingredient.
15. Vancide 51—A water solution of the sodium salts of dimethyl dithiocarbamic acid and 2-mercaptobenzothiozole. Formulated to contain 30% of the active ingredients.
16. P. e. p. s.—Polyethylene polysulfide. Formulated as a slurry to contain 60% of the active ingredient.

Results and Discussion

Experiment 1

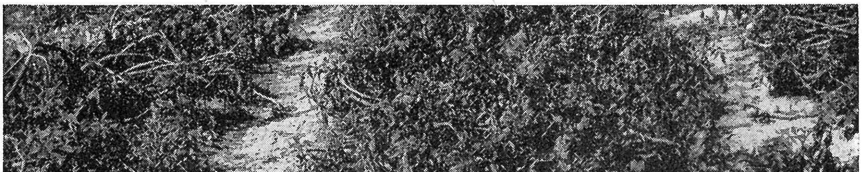
One comparatively large experiment was designed to provide for the comparison of 39 different fungicidal formulations according to their ability to control anthracnose fruit rot and defoliation due to early blight or whatever other diseases might occur. The data relative to 22 of the treatments used are given in Table 1. The remainder are omitted for various reasons, but chiefly because they were very new, ineffective, or only variations of those that are listed.

The first spray application was made on July 12; this was followed by six others. Ten-day intervals were used in most instances, but the period between the 4th and 5th and the 5th and 6th applications was shortened to 7 days in an effort to check the extremely rapid development of late blight that occurred about mid-August, and to lessen the handicap under which the organic formulations were placed, in comparison with those that contained copper. The last spray was made on September 12 and the last picking fell on October 5, following a killing frost on that date.

Late blight was first found in this experimental area on August 11. By August 20 the untreated check plots, as well as those treated with some of the fungicides which were later found to give little control of late blight, had become severely diseased. The appearance of one of the untreated check plots and one of those treated throughout the season with a copper fungicide are shown in Figure 1. Early blight was of medium severity and anthracnose fruit rot was scarce, as is shown by the fact that only 2.5 percent of the untreated fruits developed any anthracnose lesions. Septoria and Stemphylium blights were absent. Consequently, most of the variations in net yield and the percentage of culls, as shown in Table 1, resulted chiefly from differences in the ability of the various fungicides used to control late blight.

Two fixed coppers (COC-S and Tribasic) and Bordeaux mixture gave the best control of late blight infection on the fruit in this severely diseased field. The addition of p. e. p. s., which is both an adhesive and a mild fungicide, to COC-S further increased the control of late blight. This combination also gave the highest yield and the lowest percentage of culls of any formulation used in the experiment. Following the fixed coppers and Bordeaux in late blight control were two formulations of metallic copper. These were Robertson fungicide in which the copper is in the form of small particles consisting of a metallic core and a sheath of cuprous oxide, and Phelps Dodge copper paste in which the copper occurs as small, thin plates. Dithane D-14 (nabam) was in eighth place in late blight control, and was closely followed by another copper compound, known here as copper cupferron. Thus, eight of the first ten to control late blight were formulations that contained copper in one form or another. Two compounds that contain zinc ethylene bis dithiocarbamate, and a third in which the zinc was replaced by manganese (treatments 10, 11, and 12 in Table 1), were eighth, tenth and eleventh. Orthocide 406 followed this group and a tank mixture of Tribasic and Zerlate ranked next (thirteenth). It (treatment 15 in Table 1) gave considerably better control of late blight than the schedule in which the application of these two materials was alternated (treatment 16 in Table 1). Methasan slurry (ziram) gave much better results than a wettable form of the same active ingredient (see materials key). Methasan slurry was also more effective than the same chemical compound in the form of Zerlate (another ziram), and than Zac, which is a somewhat similar material. The addition of p. e. p. s. to Zerlate improved the latter somewhat in this experiment. Zac as a slurry gave better control of late blight on both the foliage and the fruit than did the wettable powder. Vancide 51 was comparatively ineffective against late blight.

Fig. 1.—Untreated check plot shows heavy damage to tomato foliage and fruit.



Plot treated with copper fungicide shows moderate damage to foliage and fruit.

The percentage of culls for any one treatment was largely determined in this experiment by the number of fruits that were affected by late blight. Net yields in turn were regulated to a considerable extent by the percentage of culls. Thus, the copper-containing formulations, which gave comparatively good control of late blight, also kept the percentage of culls down and the net yields up. The eight highest yields were from plots treated with copper, and with one exception these same treatments were lowest in culls. Net yields were low with such materials as Zerlate, Zac, and Vancide 51, largely because of the failure of these materials to control late blight on either the fruit or the foliage.

Anthracnose fruit rot was scarce in this experiment, even on the untreated fruits. It was best controlled by some of the derivatives of dithiocarbamic acid such as Zerlate, Methasan, Zac, Dithane, Parzate, and MnEBD. Orthocide 406 also gave good control of this disease.

TABLE 1. A portion of the yield and disease-control data obtained when 40 fungicidal formulations were applied to a field of tomatoes in which infection by late blight became very severe

Treatment numbers and materials		Formulas	Net yield	Culls	Fruits with anthracnose	Fruits with late blight	Foliage dead on Sept. 16
			Tons/ Acre	Per-cent	Per-cent	Per-cent	Per-cent
1	No treatment		5.9	73.5	2.5	87.5	84
2	Tribasic	3-100	27.4	11.5	0.7	5.5	29
3	Tribasic	4-100	30.6	8.8	1.0	4.3	27
4	COC-S	4-100	26.2	10.1	1.0	3.4	29
5	COC-S plus p. e. p. s.	4-½-100	32.9	8.3	1.1	2.2	27
6	Robertson fungicide	2.2-100	23.2	15.4	1.3	5.1	34
7	Phelps Dodge copper	4-100	23.5	13.1	1.0	5.8	42
8	Copper cupferron	4-100	24.6	17.6	0.0	9.7	36
9	Bordeaux	8-6-100	25.2	13.2	1.7	4.3	32
10	Dithane plus $ZnSO_4$	4-1-100	21.8	17.0	0.3	9.0	34
11	Parzate (Dry)	2-100	22.2	18.6	0.3	11.7	29
12	MnEBD	1.7-100	22.5	19.2	0.2	9.9	30
13	Zerlate	2-100	9.2	60.8	0.7	56.4	62
14	Zerlate plus p. e. p. s.	2-½-100	14.4	45.9	0.2	53.3	50
15	Zerlate plus Tribasic (Tank mix)	1-2-100	22.5	19.8	0.5	12.8	31
16	Zerlate and Tribasic alternating		21.4	25.6	0.4	22.2	42
17	Methasan slurry	3-100	19.4	25.6	0.0	15.9	32
18	Methasan wettable	1.5-100	14.4	47.7	0.6	45.4	52
19	Zac slurry	3-100	7.8	60.3	0.1	56.5	57
20	Zac wettable	6-100	8.9	61.6	1.2	65.5	66
21	Orthocide 406	2-100	21.1	23.6	0.5	12.5	47
22	Vancide 51	3-100	5.8	69.9	0.8	80.1	72
	L. S. D. at 5% level		4.0				

Experiment 2

Late blight appeared rather late in the season in a second experiment at Wooster in which tomatoes were being sprayed with various fungicides in a study of the comparative ability of the various materials to control the development of rots after the fruits were picked. Nineteen different formulations were used and the data relative to the condition of the fruit at picking time, are given in Table 2 for 16 of them. These plots were also treated at 10-day intervals with a tractor-mounted sprayer, the first application being made on July 11 and the last on September 6.

Approximately 30 percent of the fruits produced on the untreated check plots showed late blight lesions when they were picked. This was reduced to one percent by Bordeaux mixture, and such materials as Tribasic, Robertson fungicide, and MnEBD were nearly as effective. These were followed in a decreasing degree of control by liquid Parzate (nabam), Cop-O-Zink, COC-S, and Crag 658. Zerlate (ziram) and Zac were comparatively ineffective in the control of late blight, but Methasan slurry (another ziram) did considerably better. The use of alternating applications of Zerlate and Tribasic markedly reduced late blight infection below that which occurred with a straight Zerlate schedule, as it has done previously in many instances (1).

The percentage of cull fruits, which represents the sum total of all the fruit rots present as the fruits are graded at picking time, was lowest for Tribasic, followed in turn by liquid Parzate, Robertson fungicide, Crag 658, dry Parzate (zineb), COC-S, and Cop-O-Zink. Bordeaux mixture, which gave the best control of late blight infection on the fruit and ranked third from the top in foliage protection, was up to eighth in culls. Few of the yield variations were significant, although most of the treated plots were significantly better than the untreated check in net yield. MnEBD gave the highest yield, closely followed in descending order by Crag 658, the alternating schedule of Zerlate and Tribasic, Orthocide 406, and liquid Parzate.

Anthracnose fruit rot, the control of which was the primary object of the experiment, was comparatively scarce, even in the untreated check plots. As usual, most of the copper-containing formulations gave little control. The disease was nearly eliminated by Methasan, and was greatly reduced by MnEBD, Orthocide 406, the alternating schedule of Zerlate and Tribasic, and Zac. Zerlate, which usually gives good control of anthracnose, gave only average results in this experiment.

TABLE 2. Data on the comparative performance of various fungicidal materials when applied to tomatoes in an experiment on the residual effect of the fungicide on the development of fruit rots

	Treatment numbers and materials	Formulas	Net yield	Culls	Fruits with anthracnose	Fruits with late blight	Foliage dead on Sept 16
			Tons/Acre	Per-cent	Per-cent	Per-cent	Per-cent
1	No treatment		10.4	33.1	3.0	35.4	71
2	Tribasic	4-100	16.6	6.4	1.1	1.6	39
3	COC-S	4-100	16.3	9.7	2.8	3.6	40
4	Robertson fungicide	2.2-100	14.5	9.0	2.6	1.8	36
5	Copper cupferron	3-100	15.8	10.5	1.0	7.7	40
6	Bordeaux	8-6-100	16.3	10.1	2.2	1.1	34
7	Crag 658	2-100	17.7	9.2	1.5	4.5	40
8	Cop-O-Zink	4-100	16.4	9.9	2.2	3.5	37
9	Parzate (Dry)	2-100	16.0	9.3	1.2	6.0	35
10	Parzate plus $ZnSO_4$	4-1-100	17.0	7.4	0.6	2.9	37
11	MnEBD	1.7-100	18.1	12.9	0.4	1.7	31
12	Orthocide 406	2-100	17.3	16.0	0.6	14.7	44
13	Methasan slurry	3-100	15.8	12.1	0.1	9.0	30
14	Zerlate	2-100	13.5	27.8	1.2	29.2	54
15	Zerlate and Tribasic alternating		17.4	10.1	0.7	6.3	39
16	Zac wettable	6-100	13.6	26.1	0.8	25.9	47
17	Vancide 51	3-100	12.6	16.5	2.7	17.5	60

Experiment 3

A third experiment at Wooster, in which late blight appeared about mid-August, was sprayed by three different methods in a study of the comparative performance of 12 different fungicides when applied at 10-day intervals in standard and more concentrated formulations. The data relative to the standard formulations applied at 160 gallons to the acre and at a pressure of 300 pounds per square inch are given in Table 3.

This experiment was located near the one for which the data are given in Table 1, but it was on slightly higher ground. This slight difference in elevation was chiefly responsible for the fact that in Table 3 only 60 percent of the untreated fruits were infected with late blight, whereas nearly 90 percent of those in the check plots of Table 1 were affected by the disease.

The prevention of late blight lesions on the tomato fruits by some of the fungicides used in this "methods" experiments was truly remarkable. This was especially true of MnEBD and COC-S. Tribasic and Parzate (zineb) did nearly as well, and the performance of such materials as Crag 658, Robertson fungicide, Orthocide 406, and Dithane (nabam) was also very good. Zac, Vancide 51, and Zerlate were comparatively ineffective, but Methasan slurry (ziram) again did somewhat better.

This, together with the data of Table 2, shows more strongly than ever the importance of formulation in determining the performance of a given chemical compound with respect to disease control, since Zerlate and Methasan are identical chemically and Zac is a closely related material.

The best foliage condition, which was largely determined by the degree of late blight infection, and to a lesser extent by early blight, was provided by Tribasic. This was closely followed in the control of leaf infection by Crag 658, MnEBD, Parzate (zineb), COC-S, Orthocide 406, Robertson fungicide, and Dithane (nabam). The materials that failed to check the disease on the fruit also did poorly on the foliage. Culls were fewest on the plots treated with Tribasic, followed in turn by COC-S, MnEBD, and Orthocide 406. Anthracnose was somewhat more common in experiment 3 than experiments 1 and 2 (data in Tables 1 and 2). It was best controlled by Zerlate, Orthocide 406, and Parzate (zineb); and MnEBD did nearly as well. The disease was also scarce in the Tribasic plots but this was contrary to the general experience with this compound in the control of anthracnose.

There was little to choose between the net yield values for the top eight materials, however, the plots treated with Tribasic produced the largest yield, followed in descending order by MnEBD, Orthocide 406, Parzate (zineb), and COC-S. Zac gave the lowest yield of usable fruits, although it exceeded the check yield by nearly 50 percent. However, the inadequacy of the "dimethyl" dithiocarbamates (ziram) for late blight control was again clearly demonstrated.

TABLE 3. The effect of a selected group of fungicides on disease control (particularly late blight) when the formulations were applied at 160 gallons per acre at a pressure of 300 pounds per square inch

Treatment numbers and materials		Formulas	Net yield	Culls	Fruits with anthracnose	Fruits with late blight	Foliage dead on Sept 16
			Tons/ Acre	Per-cent	Per-cent	Per-cent	Per-cent
1	No treatment		10.2	55.3	5.5	59.7	79
2	Tribasic	4-100	30.3	7.3	1.2	1.1	29
3	COC-S	4-100	27.8	8.3	2.4	0.3	35
4	Robertson fungicide.	2.2-100	25.6	14.0	3 3	2.2	36
5	Crag 658	2-100	27.4	12.2	3.2	2.2	31
6	Dithane plus $ZnSO_4$	4-1-100	25.7	13.1	2.6	4.5	37
7	Parzate (Dry)	2-100	28.5	10.6	1.1	1 3	34
8	MnEBD	1.7-100	29.4	9.5	1.3	0.2	31
9	Methasan slurry	3-100	18.8	32.2	1.6	15.5	44
10	Zac slurry	3-100	15.2	40.0	2.4	34.8	47
11	Zerlate	2-100	20.8	28.2	1.1	21.9	44
12	Orthocide 406	2-100	28.7	9.7	1.1	3.3	36
13	Vancide 51	3-100	18.8	32.8	2.8	25.6	57
	L. S. D. at 5% level for 40 treatments		3.8				

Experiment 4

A fourth experiment, similar to the three just described, was conducted on a planting of tomatoes on the Apple Creek State Welfare Farm. In this experiment, approximately 40 different treatments were applied at 10-day intervals by means of a tractor-mounted sprayer. The sprays were applied at the usual 160 gallons per acre and 300 pounds of pressure. The first application was made on July 5 and this was followed by others until the last one was made on September 7. The data relative to this comparative test are given in Table 4.

Late blight developed later in this field than in those located at Wooster and, largely for this reason, caused less loss by the end of the season. It destroyed only 10 percent of the fruits in the untreated check plots. Since the degree of infection by late blight was small throughout the series, the differences between the treatments were less marked than at Wooster.

Tribasic gave the best control of late blight, followed closely by Robertson fungicide, Cop-O-Zink, Orthocide 406, and Crag 658. With the comparatively mild infection level that occurred here, many of the fungicides that were least able to control late blight in the first experiment (Table 1) gave fairly good results. Zerlate gave the least control. The best foliage condition persisted throughout the season on the plots treated with such materials as MnEBD, Methasan, Parzate (zineb), and Dithane (nabam). Early blight was responsible for most of the defoliation that occurred in this experiment. Anthracnose was comparatively scarce, and several of the plot replicates that were treated with the fixed coppers showed more of the disease than did the untreated checks. Zerlate, which largely failed to check late blight, gave the best control of anthracnose. This was closely followed by MnEBD and Orthocide 406, two materials that consistently reduced anthracnose in 1950.

Culls were fewest in the plots treated with such materials as Crag 658, Cop-O-Zink, MnEBD, Orthocide 406, Robertson fungicide, and Tribasic. They were most numerous with the dimethyl dithiocarbamates (zirams). The net yields (usable fruits) were similar with most of fungicides which gave good control of late blight. The plots treated with Cop-O-Zink produced the highest yield, followed in descending order by Orthocide 406, MnEBD, Dithane D-14, COC-S, Crag 658, and copper cupferron.

TABLE 4. The relative effectiveness of various fungicidal formulations on disease control when the infection levels remained low

	Treatment numbers and materials	Formulas	Net yield	Culls	Fruits with anthracnose	Fruits with late blight	Foliage dead on Sept. 16
			Tons/ Acre	Per- cent	Per- cent	Per- cent	Per- cent
1	No treatment		20.8	20.6	2.3	10.3	66
2	Tribasic	3-100	22.4	12.7	3.7	0.1	42
3	Tribasic	4-100	23.2	10.5	2.6	0.6	37
4	COC-S	4-100	25.6	13.4	1.4	4.0	37
5	Copper cupferron	4-100	25.2	10.8	1.0	4.8	57
6	Robertson fungicide	2.2-100	23.8	10.0	3.4	1.1	44
7	Crag 658	2-100	25.5	8.2	1.9	1.5	56
8	Cop-O-Zink	4-100	27.5	8.6	1.4	1.2	40
9	Parzate (Dry)	2-100	24.9	11.2	1.3	3.7	36
10	Dithane plus $ZnSO_4$	4-1-100	26.1	12.0	1.1	3.8	36
11	MnEBD	1.7-100	26.2	9.8	0.8	2.5	34
12	Orthocide 406	2-100	26.8	10.0	1.0	1.4	49
13	Zerlate	2-100	22.3	13.2	0.3	7.7	46
14	Methasan slurry	3-100	21.9	13.7	1.3	3.7	35
15	Methasan wettable	1.5-100	22.1	14.2	1.6	2.7	46
16	Zac slurry	3-100	22.7	13.4	1.9	3.4	37
17	Zac wettable	6-100	20.8	15.7	3.1	3.4	51
18	Vancide 51	3-100	25.4	10.3	0.6	3.4	52
	L. S. D. at 5% level for 40 treatments		3.5				

Averages (Experiments 1 to 4)

Several of the fungicides listed in Tables 1 to 4, inclusive, were used in all four experiments and the results obtained with 11 of these are averaged in Table 5. These averages give a rather complete picture of the relative merits of the various materials in the control of the foliage and fruit diseases that occurred on tomatoes in the vicinity of Wooster in 1950. The data on late blight control are the most interesting, since that disease was more severe in these experiments than was early blight or anthracnose fruit rot. Tribasic gave the best control of fruit infection, followed closely by Robertson fungicide and COC-S. MnEBD gave the best results of the ethylene bis dithiocarbamates, followed by Dithane D-14 (nabam) and dry Parzate (zineb). Orthocide 406 gave results somewhat better than the average. Methasan as a slurry was definitely more effective in late blight than its wettable twin, Zerlate. The average foliage condition, which was chiefly regulated by the severity of late blight infection, was similar with many of the materials. It was best with MnEBD, followed closely by Tribasic, dry Parzate, COC-S, Methasan, and Dithane D-14. The good ranking of Methasan was probably due more to the control it gave of early rather than late blight. Zerlate ranked low in the foliage score category chiefly because of its failure to check late blight on the leaves.

Anthracnose was best controlled by Methasan and MnEBD, with Zerlate and Orthocide 406 doing almost as well. Parzate, Dithane D-14, and Zac were also fairly effective against this disease.

Tribasic and COC-S (two fixed coppers) gave the largest reduction in culls, and also the highest yields of usable fruits. Yields were also good on plants treated with MnEBD and Orthocide 406, but Robertson fungicide gave fewer culls than either of these materials. The plots treated with Methasan slurry were definitely lower in culls and higher in yield than those that received Zerlate or Zac.

Data relative to the average performance of the two fixed copper compounds (Tribasic and COC-S), the two ethylene bis dithiocarbamates (Dithane and Parzate), and the two dimethyl compounds (Methasan and Zerlate) are shown at the bottom of Table 5. The coppers, which slightly outyielded the ethylene bis compounds, gave the better control of late blight and culls, but were slightly inferior in foliage condition and less effective against anthracnose fruit rot. The dimethyl dithiocarbamates gave the best control of anthracnose but were definitely inferior in all of the other categories, particularly in the control of late blight on the fruits.

TABLE 5. Averages of the results obtained in experiments 1 to 4, inclusive

	Treatment numbers and materials	Net yield	Culls	Fruits with anthracnose	Fruits with late blight	Foliage dead on Sept. 16
		Tons/ Acre	Per- cent	Per- cent	Per- cent	Per- cent
1	Tribasic	25.0	8.3	1.5	1.9	33
2	Robertson fungicide	21.8	12.1	2.7	2.6	38
3	COC-S	24.0	10.4	1.9	2.8	35
4	MnEBD	24.1	12.9	0.7	3.6	32
5	Dithane plus $ZnSO_4$	22.7	12.4	1.2	5.1	36
6	Parzate (Dry)	22.9	12.4	1.0	5.7	34
7	Orthocide 406	23.5	14.8	0.8	8.0	44
8	Methasan	19.0	20.9	0.7	11.0	35
9	Zerlate	16.5	32.5	0.8	28.8	52
10	Zac slurry	14.8	35.0	1.3	30.2	47
11	Vancide 51	15.7	32.4	1.7	31.7	60
12	No treatment	11.8	45.6	3.3	48.2	75
	Average values for—					
	Tribasic and COC-S	24.5	9.4	1.7	2.4	34
	Dithane and Parzate	22.8	12.4	1.1	5.4	35
	Methasan and Zerlate	17.8	26.7	0.8	19.9	44

Summary and Conclusions

Late blight has been present on tomatoes in Ohio during each of the past five years. It was very destructive in 1946 and 1950, was generally present by October 1 in 1949, and occurred in many home gardens scattered over the state in 1947 and 1948. Because of this yearly occurrence, it now may be reasonable to assume that the disease will appear each year in the future that the weather becomes favorable for its development.

Late blight is dependent on the weather for its initiation and development each year. It is favored by the simultaneous occurrence, over a period of at least 12 hours, of temperatures below 60° F. and relative humidities of 95 percent, or above. The recurrence of these conditions over an unbroken period of four or more nights makes it very likely that late blight will appear in potatoes and/or tomatoes.

The disease was found on August 11 in the check plots of an experimental block of tomatoes being sprayed with about 40 different fungicidal formulations on the Station farm at Wooster in 1950. Its appearance followed a cool and rather wet June, July and early August. There were 21 nights in June and 20 in July when the minimum temperature was 60° F. or lower and this sort of weather continued through most of August. Rainfall was slightly excessive in all three months with several rather heavy rains. This weather-disease situation made it possible to obtain an excellent comparison of the fungicides being used, according to their ability to control late blight.

The first spray application was made on the experimental areas between July 20 and 25. This was followed by six others at 10-day intervals. In two or three instances this interval was shortened to 7 days in late August when the spread of late blight became unusually rapid. It should be mentioned at this point that the 10-day schedule that was used tended to favor the more durable copper-containing formulations over the more quickly disintegrating organic compounds.

Nearly 90 percent of the fruits in the untreated check plots, in an experiment in which 40 treatments were being compared, became infected with late blight. This was reduced to 2.2 percent by a mixture of COC-S plus p. e. p. s. Eight of the ten treatments that gave the greatest reduction in fruit loss contained copper in one form or another. Dithane, Parzate, and MnEBD were all in the first eleven on the basis of late blight control on the fruits but Dithane, which gave the best results of these organics, was in eighth place.

In another experiment, in which 19 formulations were being compared, about 35 percent of the untreated fruits were found to be diseased. Seven of the ten treatments which gave the best control of late blight contained copper. Third, fifth, and ninth positions were occupied by MnEBD, and the liquid and dry forms of Parzate, respectively.

In a third experiment consisting of 12 formulations only, 60 percent of the check fruits were infected by late blight. The best control of the disease was furnished by MnEBD, followed by Parzate, Orthocide 406, and Dithane in fourth, seventh, and eighth places respectively. Copper-containing compounds, such as COC-S, Tribasic, Robertson fungicide, and Crag 658 ranked second, third, fifth, and sixth, respectively.

About 40 formulations were included in a fourth experiment. Only 10 percent of the untreated fruits were infected by late blight. When the materials used in this experiment were arranged on the basis of their ability to check fruit infection, five of the top eight contained copper. Orthocide 406, MnEBD, and Methasan occupied fifth, seventh, and eighth positions, respectively. Two Tribasic formulations gave the best control, followed by Robertson fungicide and Cop-O-Zink.

Eleven of the 40 or more formulations which were included in these experiments were used in all four. The average values for each of these eleven materials were determined for the percentages of late blight, anthracnose, culls, and defoliation, as were the average net yields of usable fruit (Table 5). The average amount of late blight infection on the fruit from the untreated check plots was 48.2 percent. Tribasic reduced this to 1.9 percent, and COC-S and Robertson fungicide held the disease to less than 3 percent. MnEBD, which gave the best results of the organic compounds used, reduced infection to 3.6 percent. Dithane and Parzate, both of which usually give excellent protection against late blight on potato foliage, reduced the average fruit loss to 5.1 and 5.7 percent, respectively. The plots treated with Orthocide 406, a promising new fungicide that gave rather good control of anthracnose fruit rot in these experiments, reduced late blight on the fruits to 8 percent. The zinc dimethyl dithiocarbamates, as represented by Methasan and Zerlate in these comparative tests, failed to give satisfactory control of late blight. Bordeaux mixture gave excellent control of late blight in the two experiments where it was used and, were it not for the injury that it frequently causes on tomatoes during the first two-thirds of the growth period, this fungicide would be even more generally used for late blight control than it now is.

Control Recommendations

With the results obtained in these experiments as a guide, the following suggestions are made for the control of late blight, as well as various other foliage and fruit diseases of canning tomatoes in Ohio:

1. Spray, or dust as a second choice, with a copper-containing fungicide at not more than 10-day intervals. The first application should be made somewhere between July 15 and 25, depending on the location in the state, the stage of crop development, the weather, and the absence or presence of late blight in the immediate vicinity, or even as much as 100 miles distant. At least four and, better still, five or six applications should be made, depending on the disease situation in late August and early September.

2. The ethylene bis dithiocarbamates (Dithane, Parzate, and MnEBD) may be substituted for the copper compounds in the above spray schedule, but their performance as dusts may not be as satisfactory as mixtures prepared with the fixed coppers.

3. If anthracnose fruit rot is a recurring hazard, then Dithane or Parzate will give somewhat better control of that disease than will any of the copper compounds. However, if the control of anthracnose promises to be a more important problem than the prevention of loss from foliage diseases in any given season or locality, then a dimethyl dithiocarbamate, such as Zerlate, should be included in the control program. This may be done by using Zerlate in alternate applications with a fixed copper, Dithane, or Parzate. The Zerlate is usually applied first in such a schedule. This program will usually give a modicum of control of the disease complex. However, results obtained in these experiments indicate that late blight will not be controlled sufficiently well by this alternating schedule when the disease becomes extremely active. Under these conditions, the grower should abandon his effort to control anthracnose and use a material more capable of controlling late blight.

   Either of the first two schedules may be used on staked tomatoes, whether grown for sale or in the home garden. The alternating schedule may be used, if the grower wishes, whenever the tomato plants are not staked or trellised to keep the fruit off the ground.

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